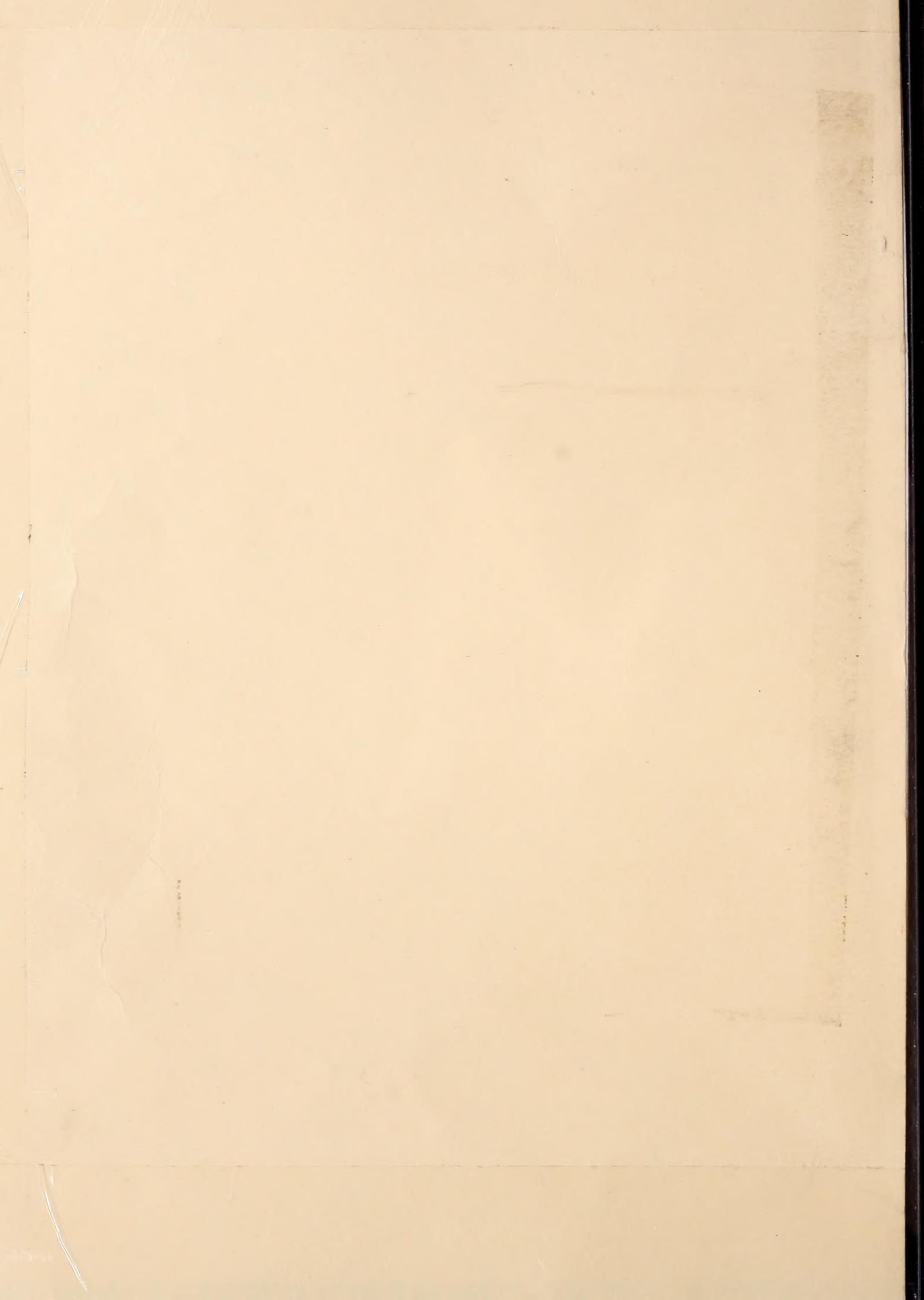


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Seasonal Progress of RADIAL GROWTH of Douglas-fir Western Redcedar and Red Alder

BY DONALD L. REUKEMA

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INTRODUCTION

To determine the duration of the growing season and the distribution of growth over the season, measurements of radial growth were made for 5 years at McCleary Experimental Forest, in western Washington.^{1/}

Information provided by this study should be of interest, not only to those concerned with measuring short-term responses to treatment or environment but also to those concerned with remeasuring trees on permanent sample plots. Results clearly show progress of growth over the season to be extremely variable from one year to another. This makes it difficult to assess the proportion of total growth completed by a given date and indicates the importance of avoiding the growing season, if at all possible, when periodic measurements are made on permanent sample plots.

The literature contains many reports of similar measurements on a wide number^{2/} of the tree species (Bannan 1962; Bormann and Kozlowski 1962).— In many cases, measurements have been more frequent and under better controlled conditions, but usually they have covered only a 1- or 2-year period. Also, few such measurements have been made on the species herein reported. Dimock (1964) reported observations on younger Douglas-fir in the same vicinity as this study, and Warrack and Joergensen (1950) reported on measurements to evaluate the effect of thinning on growth of Douglas-fir in British Columbia.

THE STUDY

Measurements were made on four groups of 10 trees each--two of Douglas-fir and one each of western redcedar and red alder. One group of Douglas-fir trees (group 1) was near the top of a hill on west-to-southwest aspect, at an elevation of about 575 feet; the other (group 2) was on a moderate, westerly facing sidehill at an elevation of about 370 feet. Cedar trees were on a flat at an elevation

^{1/} McCleary Experimental Forest is maintained by the Pacific Northwest Forest and Range Experiment Station in cooperation with Simpson Timber Co. The study was begun by George R. Staebler in 1954 and continued by Edward J. Dimock II.

^{2/} Names and dates in parentheses refer to Literature Cited, p. 14.

of about 375 feet, and alders were on a flat at an elevation of about 330 feet. Douglas-fir trees were about 65 years old in 1954; cedar and alder were about 50 years old.

Trees were chosen to minimize variations in crown class and diameter. Most were strong codominants. Starting diameters and 5-year radial growth are summarized in table 1.

Table 1.--1954 d.b.h. and subsequent 5-year radial growth
(north side) of study trees

Tree number	Douglas-fir, group 1		Douglas-fir, group 2		Western redcedar		Red alder	
	D.b.h.	Growth	D.b.h.	Growth	D.b.h.	Growth	D.b.h.	Growth
----- <u>Inches</u> -----								
1	15.6	0.312	15.9	0.423	10.3	0.715	10.4	0.218
2	17.1	.255	22.7	.567	10.5	.284	10.9	.256
3	15.7	.383	17.3	.406	11.6	.205	10.3	.393
4	16.6	.328	17.5	.107	10.9	.442	12.7	.287
5	18.9	.372	20.8	.372	8.4	.292	11.0	.234
6	15.9	.427	19.8	.208	10.5	.428	9.4	.311
7	16.4	.804	21.2	.721	10.6	.218	9.1	.101
8	15.3	.414	20.9	.897	9.5	.393	8.5	.212
9	15.4	.432	18.2	.320	9.3	.303	9.4	.161
10	17.5	.283	20.4	.483	10.0	.345	8.4	.110
Average	16.4	.401	19.5	.451	10.2	.362	10.0	.229

Measurements were made in thousandths of an inch with a dial gage dendrometer. Roundhead brass screws, driven into the wood of the trees, were used for bearing points, and 3/8-inch squares of copper or aluminum, stuck to a smoothed portion of the bark with fast-drying model airplane cement, were used for contact points. The screws formed the corners of a right triangle, so that no screw was directly below the point where growth was measured.

Changes in radius were recorded cumulatively from the first measurement in April 1954 to the final measurement in November 1958. During each growing season, measurements were made weekly until it was established that true growth had been underway for at least 2 weeks, and then every 2 weeks until growth apparently stopped. In group 1, radius changes were recorded on four sides of the trees--north, east, south, and west. In all other groups, measurements were made only on the north side of trees.

RESULTS AND DISCUSSION

Changes in radius due to moisture and the adequacy of measuring trees on only one side are discussed first to provide a background for interpreting progress of seasonal growth. Variations in precipitation and temperature are also presented to show their relationship to year-to-year differences in pattern of radial growth.

Changes in Radius Due to Moisture

Shrinking and swelling of tree trunks due to moisture changes masks actual growth in many instances, and the reader should be aware that reported changes in radius are the sum of true growth and this shrinking or swelling (Kozlowski 1962).

Data collected during the early part of the 1956 growing season from a setup on a recently dead tree showed the considerable impact that moisture changes can have. The most drastic changes were shrinkage of 0.01 inch during the period April 6-20 and swelling of the same amount during the period June 1-15; a hundredth inch is about 15 percent of average annual growth on nearby living codominant trees. The dead tree did not provide a completely valid measure of shrinking and swelling due to moisture changes in live trees, but it was indicative of the effect moisture alone can have.

Substantial changes in radius between the last measurement in the fall and first measurement the following spring are due in part to swelling and shrinking. During the winters of 1954-55, 1955-56, and 1957-58, most trees showed some increase in radius, the increase generally being greater on Douglas-fir than on cedar and alder. Between the 1956 and 1957 measurements, however, the north radius of most trees shrank substantially--8.5 percent of the 1956 seasonal growth for Douglas-fir, 18.5 percent for cedar, and 30.0 percent for alder. Over the other three winters, increase in radius of Douglas-fir averaged 6.9 percent of the seasonal growth; cedar, 3.2 percent; and alder, 4.6 percent.

Tree trunks also undergo small amounts of diurnal shrinking and swelling, which could have some effect on changes from one measurement to another (Kozlowski 1962). However, most measurements were made in late morning, so this factor had negligible influence except as reflected in the seasonal variation.

Adequacy of One Measurement Per Tree

On the 10 Douglas-fir trees where radial changes were measured on four sides, amount of annual growth differed substantially and significantly between sides, as well as between years (table 2). Growth averaged 42 percent greater on the east side than on the south side.

Table 2.--Average seasonal radial growth of Douglas-fir, by side of tree and year (basis: 10 trees)

Year	North side	East side	South side	West side
<u>Inches</u>				
1954	0.089	0.087	0.057	0.074
1955	.102	.110	.081	.093
1956	.057	.062	.043	.050
1957	.072	.082	.058	.061
1958	.076	.077	.058	.056
Average	.079	.084	.059	.067

This relationship between growth rate and cardinal direction may indicate a buildup in windfirmness in response to southwesterly winds (Ruth and Yoder 1953), or it may otherwise be associated with the near ridgeline position of these trees. Other factors--perhaps relative competition on various sides of the tree, slope, root grafts, etc.--sometimes overshadowed this trend.

Despite differences in amount of growth, progress of growth during the season was very similar for all sides (table 3). The

Table 3.--Variation between sides of Douglas-fir trees in progress of
 seasonal radial growth (basis: 10 trees)

Year	Date	Percent of radial growth completed			
		North side	East side	South side	West side
1954	Apr. 25	-5	-6	-9	-7
	May 25	11	10	3	8
	June 24	40	41	39	39
	July 24	65	67	66	64
	Aug. 23	88	90	91	90
	Sept. 22	99	99	97	99
1955	Apr. 25	10	8	10	7
	May 25	20	19	21	19
	June 24	48	49	53	51
	July 24	74	75	79	77
	Aug. 23	93	94	95	94
	Sept. 22	97	98	98	98
1956	Apr. 25	-5	-6	-13	-11
	May 25	25	22	16	22
	June 24	51	45	43	46
	July 24	78	71	65	71
	Aug. 23	93	90	86	88
	Sept. 22	93	91	87	89
1957	Apr. 25	5	4	4	4
	May 25	38	37	38	42
	June 24	64	63	64	69
	July 24	81	79	81	85
	Aug. 23	94	93	94	96
	Sept. 22	92	91	88	91
1958	Apr. 25	5	5	5	5
	May 25	45	43	44	47
	June 24	77	74	80	81
	July 24	74	73	72	72
	Aug. 23	83	82	78	80
	Sept. 22	91	90	87	87

average maximum deviation between sides, in percent of growth completed by any given date, was less than 5 percent; the greatest deviation was 13 percent. In 1956, relative growth consistently progressed more rapidly than average on the north side and less rapidly on the south side. In 1957, relative growth progressed slightly more rapidly on the west side. However, even these differences were fairly minor, and in other years there were no consistent differences between sides.

Many minor differences between sides appear to be due partly to shrinking and swelling. Apparent changes due to moisture were generally of about the same magnitude on all sides. Therefore, when these changes are expressed as percent of total seasonal growth, they are relatively greater on sides making less than average growth.

Measurement on only one side of the stem is apparently sufficient for determining progress of radial growth throughout the season, although not for determining amount of growth.

Beginning and End of Growing Season

The time that growth begins in the spring and ends in the fall can only be approximated, because of the masking effect of shrinking and swelling. Generally, most of the true growth of all species apparently took place between mid-April and early September. However, there was considerable year-to-year variation (figs. 1-5).

For Douglas-fir, distinct turning points in the growth curves marked the apparent start of growth about May 10 in 1954 and April 20 in 1956 and 1957. In 1955 and 1958, growth apparently started in early April. Growth of cedar and alder apparently started about 3 weeks earlier than Douglas-fir in 1954; growth of alder started about a month later than Douglas-fir in 1958.

The period of rapid growth of Douglas-fir ended about September 15 in 1954; August 15 in 1955, 1956, and 1957; and June 25 in 1958. However, only in 1954 was growth completed by the date indicated. In 1955, a slow increase in radius continued to the last measurement in mid-October. In other years, there were irregular changes in radius, with some growth apparently taking place into October and, perhaps, November. Corresponding dates for other species differed only slightly.

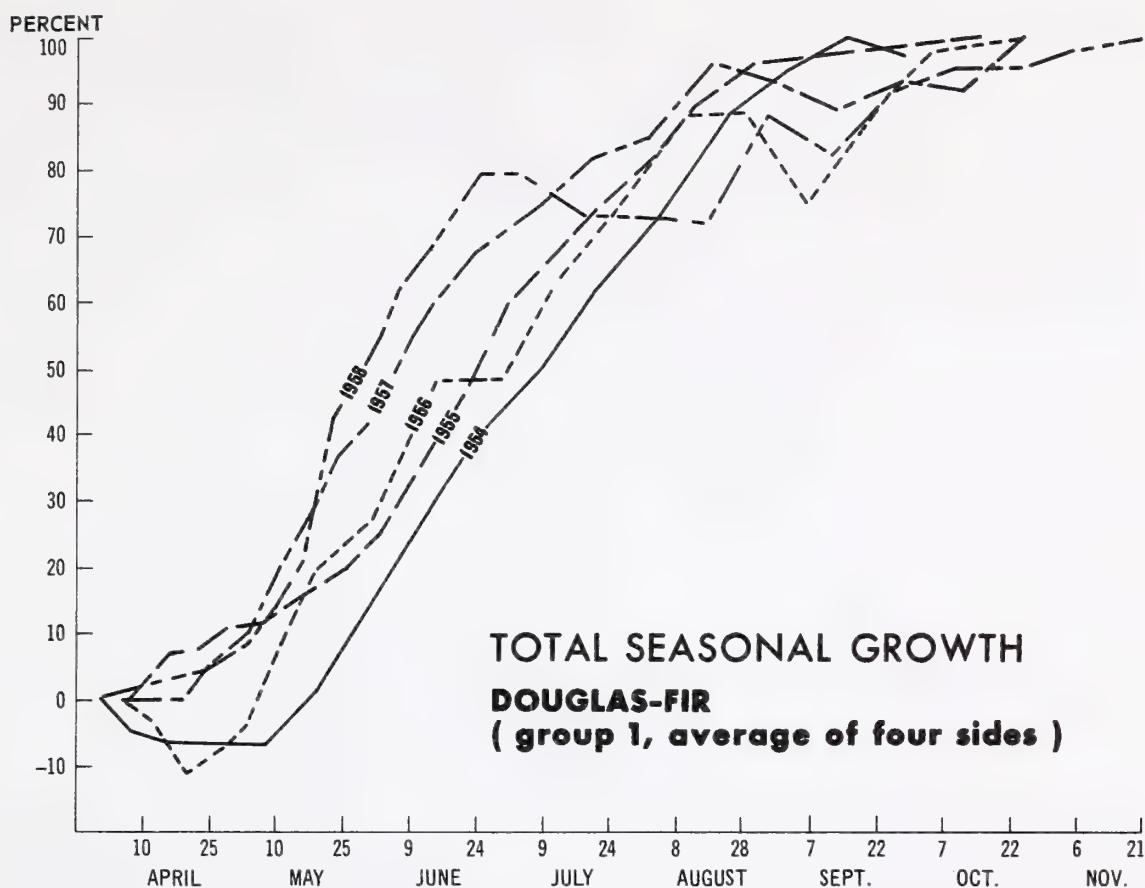


Figure 1.--Seasonal distribution of radial growth on Douglas-fir (group 1, average of four sides), 1954-58.

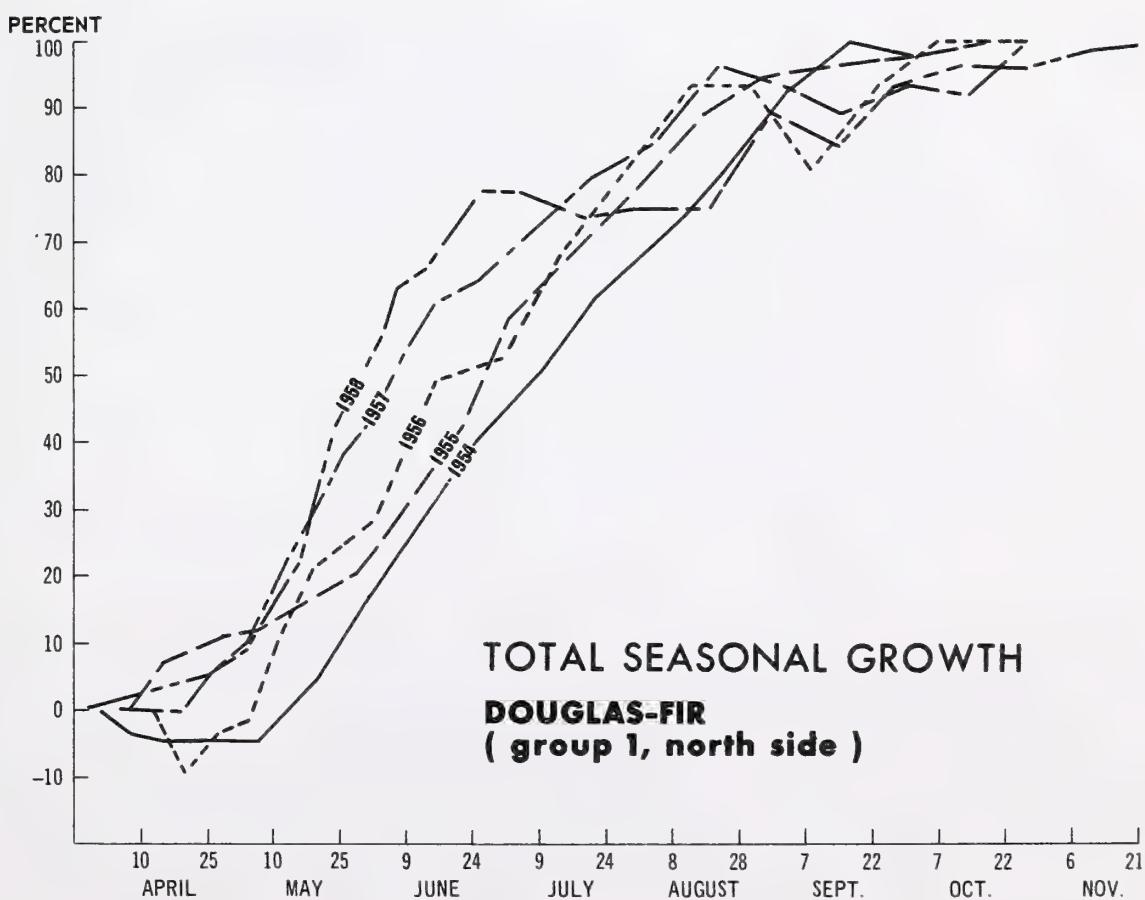


Figure 2.--Seasonal distribution of radial growth on Douglas-fir (group 1, north side), 1954-58.

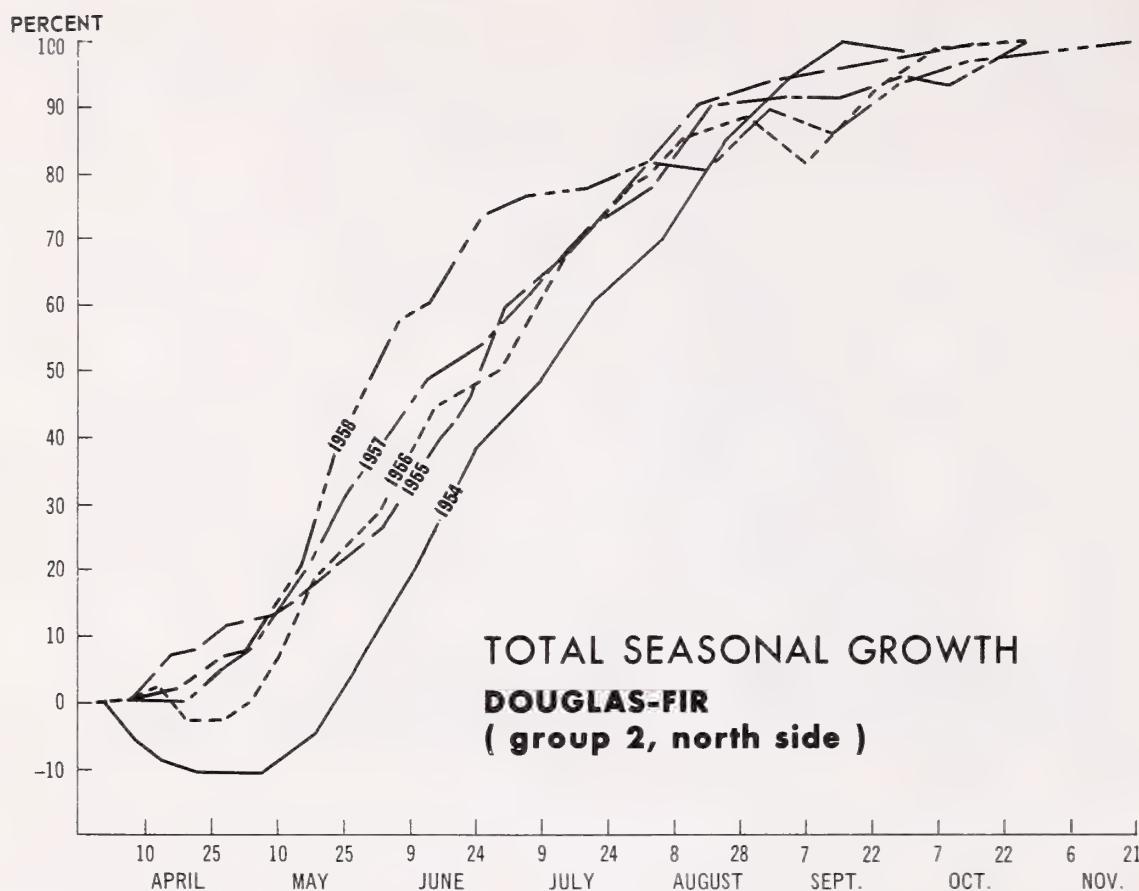


Figure 3.--Seasonal distribution of radial growth on Douglas-fir (group 2, north side), 1954-58.

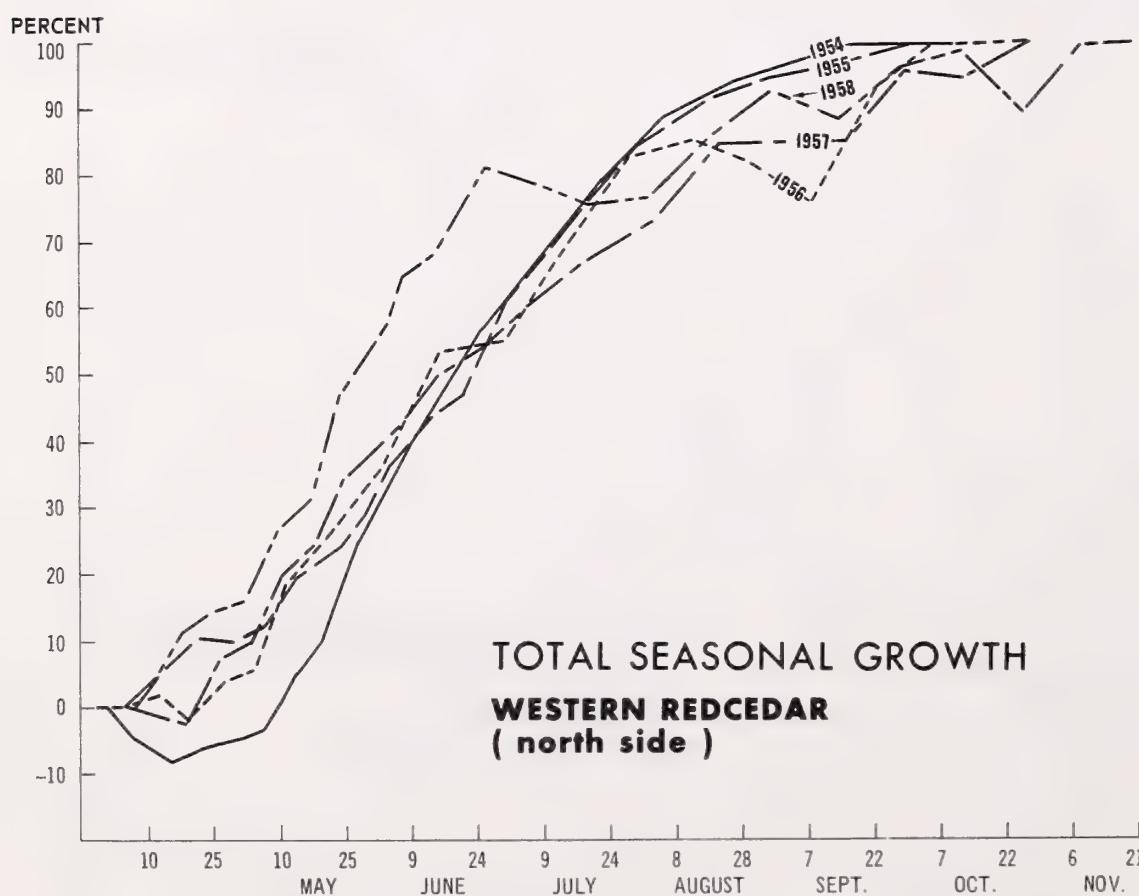


Figure 4.--Seasonal distribution of radial growth on western redcedar (north side), 1954-58.

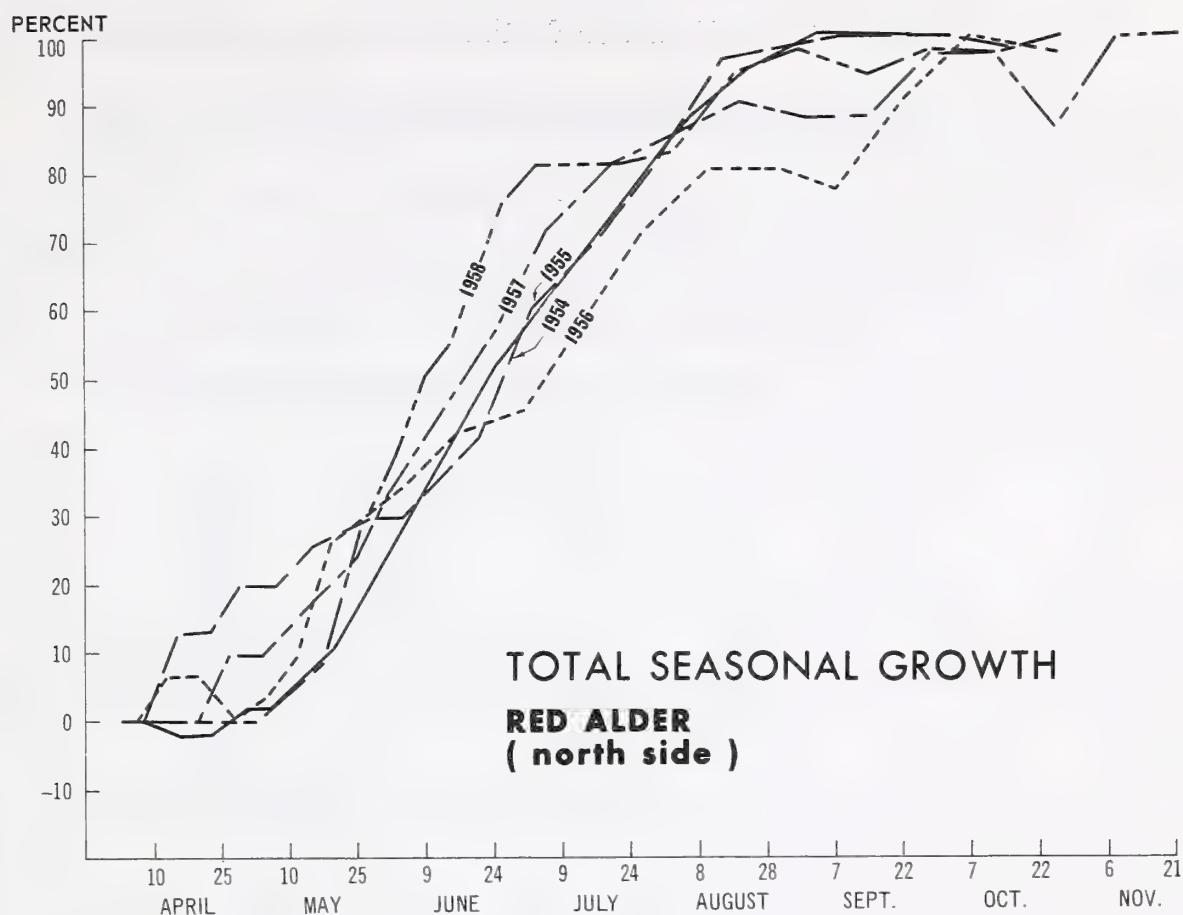


Figure 5.--Seasonal distribution of radial growth on red alder (north side), 1954-58.

Distribution of Growth Over the Season

The distribution of growth over the season is perhaps most easily visualized when growth to any given date is expressed as a percent of the total seasonal growth (figs. 1-5). For illustrative purposes, the growing season has been taken as the period from the first measurement to the highest reading. The trend lines show actual growth plus or minus changes due to shrinking and swelling. Since there was some growth between measured periods, the indicated percent of total growth completed by a given date would differ somewhat if measurements had been taken over a longer or shorter period, but the impact on the total curve would not be appreciable.

Relative growth distribution for each year is summarized in table 4 for Douglas-fir in group 1 (average of four sides) to further illustrate differences between years. On the average of the 5 years, growth was 27 percent complete by May 25. However, this varied from 8 percent in 1954 to 45 percent in 1958. Similarly, growth completed by June 25 averaged 57 percent but varied from 40 to 79 percent.

Table 4.--Seasonal distribution of growth for Douglas-fir,
group 1 (average of four sides), by years

Date	1954	1955	1956	1957	1958	Average
<u>Percent of total seasonal growth</u>						
Apr. 25	-7	9	-9	5	5	1
May 25	8	20	23	38	45	27
June 24	40	50	48	67	79	57
July 24	64	76	73	82	73	74
Aug. 23	90	95	89	95	81	90
Sept. 22	99	98	89	92	90	94
Oct. 22	--	--	100	100	96	99
Nov. 21	--	--	--	--	100	100

Even during the generally most active part of the growing season, shrinkage sometimes offset or exceeded growth. The most notable example was during the period June 24 through August 15, 1958. On Douglas-fir (group 1), "growth" was 79 percent completed by June 24 in 1958, compared with the average for this date of 57 percent. But on August 15, it was only 72 percent completed, compared with the average for that date of about 88 percent (fig. 1). In 3 of 5 years, there were shrinkages in mid-September. Actual growth is probably nearly completed by this time, but weather-caused fluctuations still have substantial impact.

The relative seasonal distribution of growth of the three species likewise varied from one year to another. In 1955 and 1957, distribution of growth was nearly the same for all species. In 1954, growth of both cedar and alder was more advanced than that of Douglas-fir throughout the season, whereas in 1956 that of Douglas-fir was more advanced during parts of the season. In 1958, cedar grew similarly to Douglas-fir; alder started slowly and then went ahead. Both cedar and alder shrank substantially in October, but Douglas-fir continued to increase in radius.

Growth and Weather

Variations in amount and seasonal distribution of precipitation (fig. 6) undoubtedly caused many of the variations in growth patterns. For example, decreases in radius in April 1956 and July 1958 were associated with exceptionally low rainfall. On the other hand, delayed growth in 1954 and rapid growth in May of 1957 and 1958 showed no apparent relationship to precipitation. The latter two may be a reflection of comparatively warm April-May temperatures (table 5). That such relationships cannot be seen for all variations is probably because the combined effect of precipitation, temperature, and wind cannot be properly assessed from available data.

Differences in total growth in 1954 and 1955 are difficult to explain since weather was very similar in the 2 years. The poor growth in 1956 and erratic growth thereafter can be attributed, in

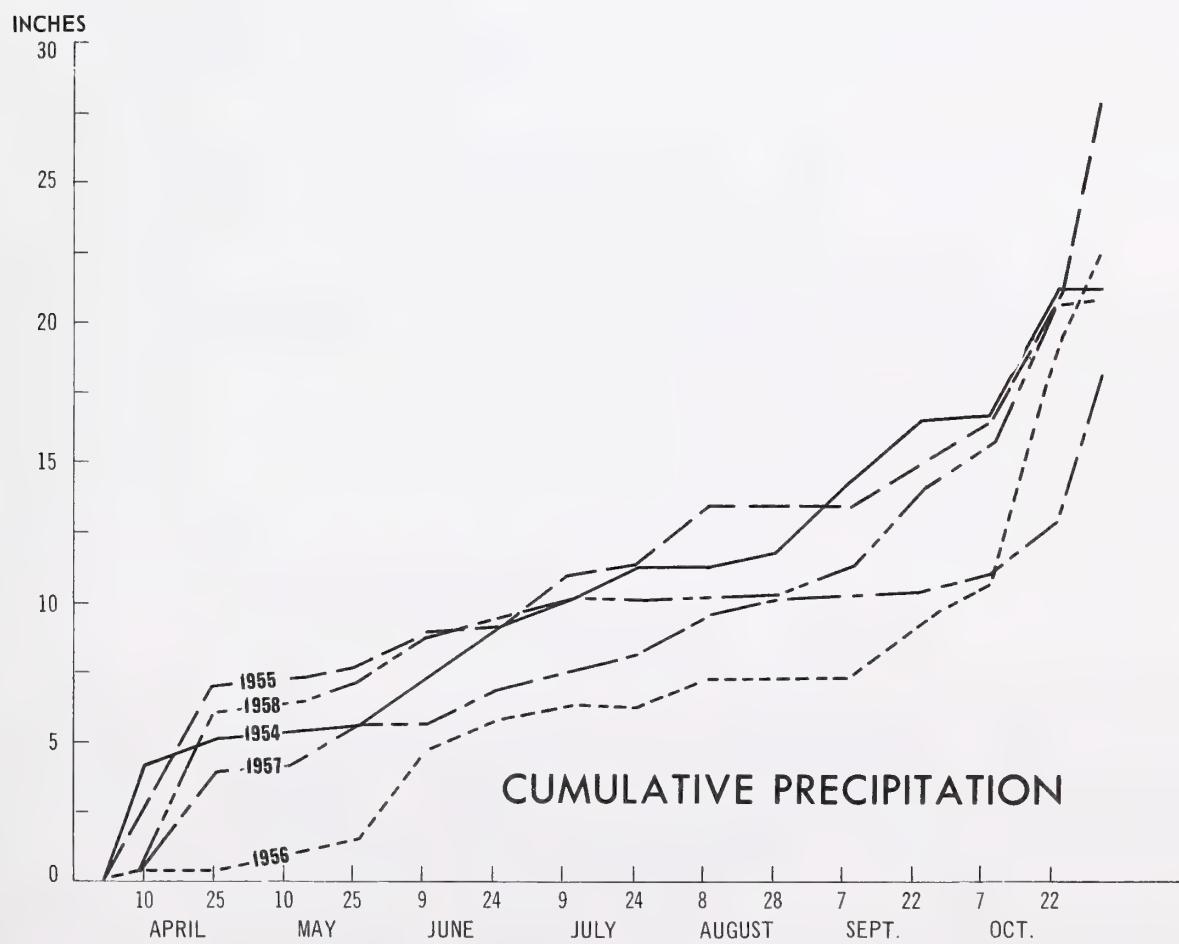


Figure 6.--Cumulative distribution of precipitation, 1954-58, Elma, Wash.

Table 5.--Average monthly temperature, Elma, Wash.^{1/}

Month	Year				
	1954	1955	1956	1957	1958
<u>Degrees F.</u>					
April	46.6	45.0	52.3	50.7	50.7
May	53.8	51.9	57.9	57.5	60.8
June	(2/)	58.9	56.8	60.4	65.0
July	58.4	59.4	64.1	60.1	67.8
August	61.4	61.0	62.8	62.4	64.3
September	59.5	58.0	58.3	62.9	57.8
October	51.4	51.2	50.3	51.7	53.0

^{1/} U.S. Weather Bureau (1954-58). U.S. Weather Station at Elma is about 10 miles west of McCleary Experimental Forest.

^{2/} Not available.

part at least, to damage by the November 1955 freeze.^{3/} Growth subsequent to the freeze was apparently affected by relative damage to competing trees as well as damage to the subject tree, with growth of a few trees being stimulated by improvement in competitive position.

^{3/} The cold wave that swept through the Pacific Northwest in November 1955 killed many forest trees. Countless others were damaged but survived (Duffield 1956). In one area in western Washington, 1956 growth rate of codominant trees averaged about half of the 1954-55 growth rate. Radial growth improved thereafter, but magnitude of recovery varied considerably between trees (Reukema 1964).

SUMMARY AND CONCLUSIONS

Measurements over five growing seasons on 20 Douglas-fir, 10 western redcedar, and 10 red alder trees provide information on distribution of growth over the growing season. Changes in radius on the north, east, south, and west sides of 10 Douglas-fir and the north side of all other trees were measured weekly or biweekly with a dial gage dendrometer.

Radial changes measured included true growth plus or minus swelling or shrinking due to moisture, which masked true growth in many instances. On trees measured on four sides, growth rate tended to be greatest on the east side and least on the south. However, trends of radial changes were generally very similar for the north side and the average of four sides.

Generally, most of the true growth of all species apparently took place between mid-April and early September. However, increases in radius started in early April in 1955 and 1958 and not until about May 10 in 1954. Rapid growth continued until mid-September in 1954, but only until late June in 1958. Irregular changes in radius followed the periods of most rapid growth, with some growth taking place in October or later.

The distribution of growth over the season differed considerably from one year to another. Also, shrinkage sometimes exceeded growth, so that percent of "growth" completed by a given date was less than for an earlier date in the same year. The relative seasonal distribution of growth among species, likewise, varied from one year to another.

Much of the yearly variation can easily be linked with weather. That such a relationship cannot be seen for all variations is probably because the combined effect of precipitation, temperature, and wind cannot be properly assessed from available data.

The data clearly indicate the importance of avoiding measurements during the growing season, if at all possible, because proportion of growth completed by a given date is difficult to assess. If it is necessary to measure during the growing season, or to work with past measurements made during the growing season, the curves developed in this study can be used as a basis for a crude interpolation of amount of growth completed. The average proportion of growth completed by Douglas-fir by specified dates is shown in table 4. Despite

year-to-year differences, averages for other species were nearly the same as for Douglas-fir. The growth curves should be applied with caution, however, because seasonal distribution of growth may vary not only from year to year but also with stand age, density, and location.

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